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RESEARCH AND THE EVOLUTION OF QUIETER CONCRETE ROAD SURFACES IN THE UNITED KINGDOM

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ABSTRACT

Traditionally, concrete road surfaces on high-speed roads in the UK were textured by transverse brushing or grooving. However, the technical difficulties in achieving the required minimum texture often resulted in over-texturing and concrete roads retained a reputation for noise nuisance. In an effort to resolve this problem, research was carried out on the influence of texture profile characteristics on the noise associated with various surfaces. This work included full-scale trials of a randomly textured concrete surfacing, called Exposed Aggregate Concrete (EAC), alongside other textured concrete surfaces. The research determined the relation between texture profile characteristics and pass-by noise levels. This paper describes how quieter concrete surfaces have been developed for use in the UK.

1 - INTRODUCTION

The use of concrete as a road surfacing material is an attractive option for highway authorities because of its record as a durable and low maintenance alternative to bituminous mixtures. Consequently, during a particularly rapid expansion of the network, concrete surfaces were frequently used in the UK for trunk roads in areas where there was a suitable supply of aggregate. However, the population quite clearly associates concrete road surfaces with more noise than with bituminous road surfaces. Research by TRL helped optimise the acoustic performance of such surfaces without comprising safety. However, a factor that contributed to the excess noise was the practical difficulty of achieving the minimum level of texture needed for safety on conventional brushed concrete surfaces. In addition, media attention and increased awareness of particularly quiet road surfaces such as Porous Asphalt have heightened public perception of the difference between concrete and bituminous surfaces.

In 1992 the Minister for Roads announced new measures to combat the problems of road traffic noise. The most significant elements of this were restrictions on the further use of conventional concrete surfaces on all roads carrying traffic flows greater than 75,000 vehicles per day and research to evaluate alternative construction techniques that would result in quieter concrete surfaces. An interim restriction on the maximum texture depth permitted on brushed concrete surfaces was also introduced to control the level of tyre/road noise where they were still used.

The research was to include trials of a method of texturing concrete surfaces called Exposed Aggregate Concrete (EAC) which had been used in a number of other European countries. The texture of this trial surface was greater than continental practice, in order to meet the minimum texture depth requirements specified in the UK to maintain high-speed skidding resistance. These same trials also considered the use of the US practice of texturing concrete surfaces using tines and a burlap drag. Following this and other trials reported here, EAC was approved for use in the UK whilst the use of transverse texturing on new concrete roads is no longer permitted by the Highways Agency [1].

2 - PREVIOUS WORK

In an extensive research programme in the 1970's, TRL examined the performance of both random and transverse textured surfaces [2]. This work showed that the noise level of light vehicles was related to the percentage fall in braking performance with increasing speed. In turn, braking performance was shown to be related to texture depth and the relations for concrete and bituminous surfaces were derived. It was found that no significant tonal effects were generated by transversely texture surfaces provided the texturing was randomly distributed in the direction of travel. It was also found that the noise levels on grooved surfaces could be related to the cross-sectional area of grooves. It was concluded that the optimum design for noise, safety and durability would be obtained by using deep narrow grooves. Light vehicle noise measurements were conducted on trial sections that gave levels that were comparable with those for a randomly textured bituminous surfacing with equivalent skidding performance.

The results of this research were used to help develop the national noise prediction methodology. It was also used for many years as the basis of the specifications for high-speed roads. However, in order to avoid sawing grooves in brushed concrete surfaces with insufficient texture, contractors tended to apply excess texture and this resulted in higher levels of tyre/road noise. Therefore, in 1992, the Highways Agency began a research programme with the Transport Research Laboratory to investigate characteristics and specifications of concrete road surfaces that would meet UK safety requirements without causing unacceptable noise levels.

3 - STUDY SITES

Initially the study considered two trial sites. The first of these was on a 3.4 km length of the M18 Motorway in Northern England. Four different surface types were laid for comparative assessment and the road was opened to traffic in autumn 1993. The two novel concrete surface types on trial were the Exposed Aggregate Concrete (EAC) and transversely tined concrete with a burlap drag. These were compared with conventional Hot Rolled Asphalt (HRA) and brushed concrete surface motorway surfacings.

The EAC sections were constructed in two layers using the normal contractors plant. The upper layer was constructed with approximately 1300 kg/m^3 of 10 mm maximum sized coarse aggregate. The surface was then sprayed with a chemical retarding agent that slowed the setting of the surface layer of cement mortar. After allowing an appropriate time period for the underlying concrete base to cure (i.e. between 12 and 30 hours depending upon weather conditions) the surface cement mortar was removed by mechanical brushing which exposed the coarse aggregate to form the surface texture. The exposed aggregate created a random texture visually comparable to a conventional asphalt with chippings and the same texture requirements were imposed for the EAC trial surfaces (average texture depth measured by the volumetric sand patch method no less than 1.5 mm) as required for conventional HRA surfaces. Figure 1 shows the brushing process used to expose the aggregate.

Figure 1: Brushing the surface to expose the aggregate.

The burlap and tined surface was created by dragging burlap longitudinally along the smooth concrete surface to provide microtexture. Randomly spaced 3 mm wide steel tines were then drawn transversely across the carriageway to give macrotexture. The texture specifications for this surface were the same as

those applied to the conventional brushed concrete. The sand patch texture depth specified in this case was 1.0±0.25 mm.
The second exposed aggregate trial was on the A50 trunk road near Derby in Central England and was opened in the Spring of 1995. The class of aggregate required to meet the wear criteria for the less heavily trafficked A50 was slightly lower and there was a higher aggregate density in the concrete mix. A new HRA surface laid nearby was available for direct comparison. Full details of the specifications of these trials were given by Hewitt et al [3].
Following these initial trials, more recent uses of EAC have been investigated. On the A13 near London, the pavement was laid in a single slab and the maximum stone size was increased to 14 mm. The original 10 mm aggregate specification for EAC was used on the A449 in Gwent and EAC has most recently been trialed as an inlay to replace a bituminous section of the nearside lane on the M23 south of London. This was designed to provide a durable surface on the most heavily trafficked lane of the carriageway.

4 - ACOUSTIC PERFORMANCE

At each of the road sections, locations were chosen where vehicle noise measurements adjacent to each of the surfaces could be carried out using the Statistical Pass-by (SPB) method [4]. In this method the maximum A-weighted noise level and the simultaneous speed are measured at the roadside of a significant number of individual vehicles selected from the traffic stream. The measurement microphone was located at 7.5 m from the centre of the test lane and was connected to a one-third octave analyser. All of the vehicles measured were categorised into one of two vehicle classes, 'light' (i.e. cars and small vans) and 'heavies' (heavy goods vehicles). A regression of noise against the logarithm of vehicle speed was performed for both vehicle groups. The maximum vehicle noise levels were then calculated at a reference speeds of 110 km/h and 90 km/h for lights and heavies respectively.

Road	Surface type	No. sites	Mean SPB vehicle noise levels in dB(A)	
			Lights [at 110 km/h]	Heavies [at 90 km/h]
M18	Brushed concrete	1	84.6	88.4
M18+A50	HRA	3	83.4	87.8
M18	Tined	1	82.6	87.4
M18+A50	EAC (10 mm)	6	82.1	86.5
A449	EAC (10 mm)	2	83.4	86.6
A13	EAC (14 mm)	2	84.3	87.9
M23	EAC inlay (10 mm)	2	84.2	88.1

Table 1: Results of SPB measurements on EAC and other surfaces in first three months.

The results show that the noise levels from light vehicles travelling on the M18/A50 EAC trial surfaces were 1.3 and 2.5 dB(A) lower than those on the conventional HRA and brushed concrete surfaces respectively. Similarly, the noise levels for the heavy vehicles were 1.3 and 1.9 dB(A) lower. For the tined concrete surface, the light vehicle noise levels were again lower than on the conventional surfaces. Clearly, the acoustic performance of subsequent EAC surfaces laid on the A13 and M23 has not yet mirrored that of the earlier trial surfaces. One factor that has become apparent is that the texture is more variable on these surfaces and this may be related to the construction processes used in each case.

5 - RELATIONSHIP WITH TEXTURE

In order to examine the influence of surface texture on noise levels, use was made of a laser profilometer that provides a detailed profile of a continuous longitudinal trace along the road surface. Much research has been devoted to developing better statistics of the road surface texture in an attempt to correlate these with noise emissions. A popular method has been to characterise surface texture in terms of its pseudo-periodic longitudinal features using Fourier methods. For convenience, three broad ranges of texture wavelength (λ) have been defined as having significantly different effects on tyre/road interactions [5]. These are microtexture ($\lambda < 0.5$ mm), macrotexture (0.5 mm $< \lambda <$ 50 mm) and megatexture (50 mm $< \lambda <$ 500 mm).
TRL examined the relationship between SPB noise levels and the amplitude of a broad range of longitudinal surface texture wavelengths. From this, strong differences in the degree of correlation between the amplitude of irregularities in the road surface texture and noise frequencies emerged for different types of road surface in these and other trials [6]. The results showed that the relationships for surfaces with transverse textures, such as brushed concrete, were clearly distinguishable from those with random

texture, such as EAC An example of these differences is shown in Figure 2 which shows the degree of correlation between the one-third octave noise levels for light vehicles and texture amplitudes in octave wavelength bands on the two types of surface.

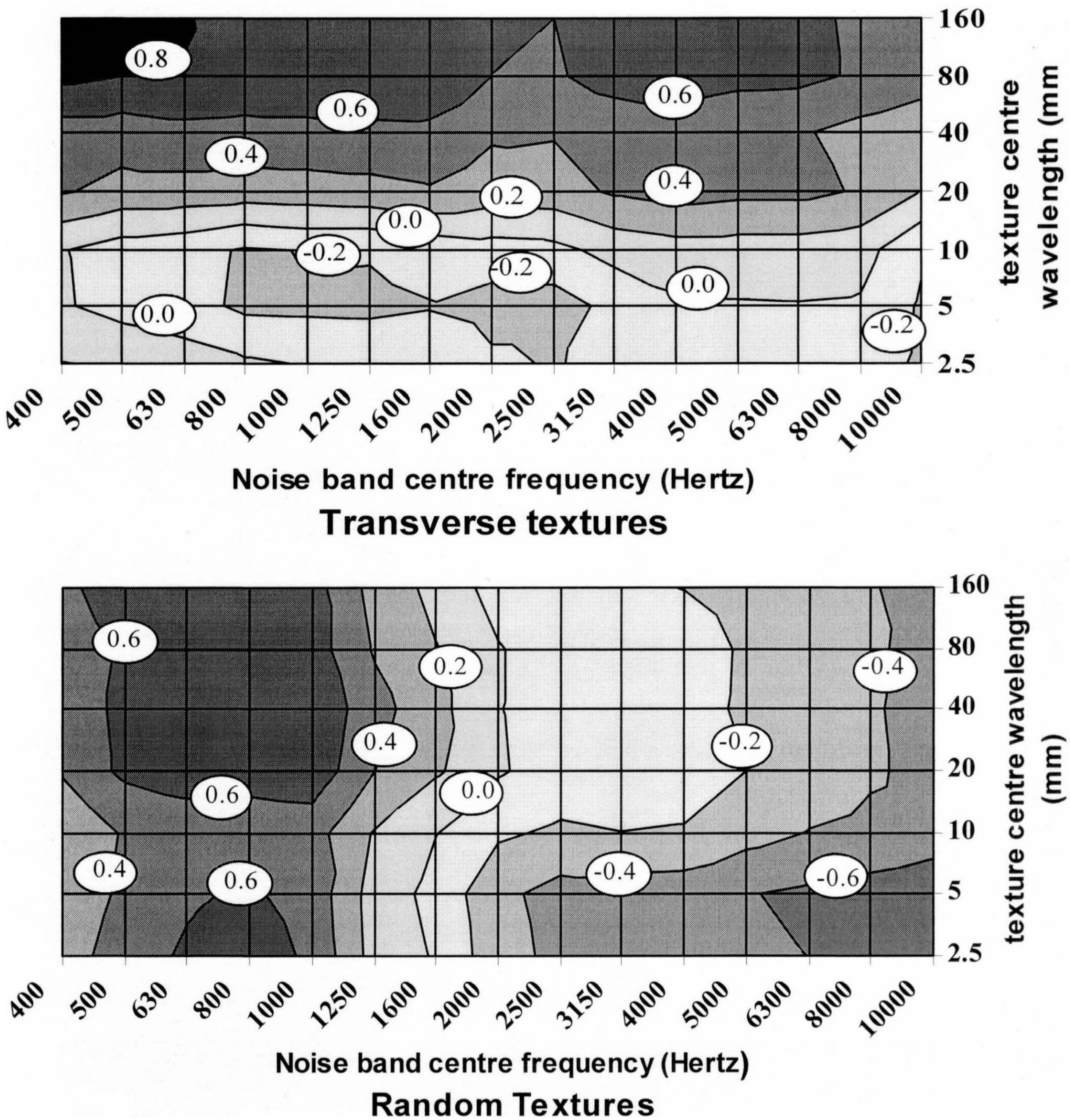

Figure 2: Correlation of light vehicle SPB frequency levels and octave band texture amplitudes.

The contours show the degree of correlation between the amplitude of the texture and noise levels within the frequency bands shown. Transversely textured surfaces show strong positive correlations across a broad range of frequencies for texture wavelengths around 80 mm leading to an expectation of noise levels increasing with amplitude of megatexture. The weaker negative correlations over a narrow range of frequencies in the 5 mm texture band support previous findings of a reduction in noise with increasing amplitude for this range of texture wavelengths [7]. A very different picture emerged for random textures in which the important frequencies of pass-by noise (i.e. 800 Hz and 1000 Hz) were positively correlated with a range of texture wavelength bands from 160 mm to 20 mm. There were negative correlations between shorter wavelength amplitudes and higher noise frequencies. Taking account of these findings for random surfaces, further work has been undertaken to establish the strength of relationships between noise emissions and megatexture spanning texture wavelengths between 56 and 226 mm. Distinct relationships were found between the overall noise level and megatexture amplitude for the two types of

surface texture. These results showed that the pass-by noise levels for light vehicles could be determined with some accuracy from the megatexture amplitudes of transverse textured surfaces, but that this was not sufficient to characterise randomly textured surfaces. It was clear that further research was needed to account for the residual scatter in the noise data for these surface types.
In parallel with the work on noise and texture, further research was conducted into the skidding performance of different types of road surfaces. This work showed that the absolute level of high-speed skidding resistance for all types of surfacings can be predicted from their low-speed skidding resistance and the RMS texture depth [8]. This relation was found to be independent of the type of texture considered. Clearly, transverse textures were at a disadvantage, because they have relatively low texture depths compared with random textured surfaces. Indeed it was found that the level of texture required for safety on a transversely textured concrete would preclude it being able to match the noise levels associated with modern road surfacing materials [9].

6 - SUMMARY

The trials have demonstrated that concrete roads combining good acoustic performance and meeting safety requirements can be produced using the EAC technique. At the same time, it has become clear that, despite our improved understanding of the influence of texture, conventional brushed concrete surfaces cannot now meet modern performance standards for noise without unacceptable reduction in texture depth. As a result, transversely textured concrete surfaces are no longer used for new national roads in the UK. EAC, which has a random texture, is now the only concrete surfacing permitted by the Highways Agency.
Detailed analyses of the geometrical characteristics of the random surface textures, such as EAC, are currently being undertaken in an attempt to separately characterise noise emissions and skidding resistance. Even if the mechanisms of noise generation and skidding resistance are physically attributable to similar features of surface texture, it may still be possible to further reduce tyre noise without prejudicing safety, if appropriate surface texture descriptors can be found to provide a better means of specifying requirements to contractors.

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REFERENCES

1. **Highways Agency, Scottish Office Development Department, Welsh Office and Department of the Environment for Northern Ireland.**, *Design Manual for Road and Bridges, Vol. 7, Section 5, HD 36/99 Surfacing materials for new and maintenance construction.* The Stationary Office, 1999

2. **Franklin, R E, Harland, D G, Nelson, P M.** , *Road surfaces and traffic noise*, Transport Research Laboratory, 1979

3. **Hewitt A P, Abbott P G and Nelson P M**, *Alternative textures for concrete roads: results of M18 and A50 trials.*Transport Research Laboratory, 1997

4. **International Standards Organisation**, ISO 11819-1. Acoustics - Method for measuring the influence of road surfaces on traffic noise - Part 1: The Statistical Pass-by method, 1997

5. **PIARC Technical committee on surface characteristics** , Optimisation of surface characteristics, In *PIARC XVIIth World Road Congress, Brussels*, 1987

6. **Abbott P G and Phillips S M**, Vehicle noise levels derived from the statistical pass-by method and road surface texture, In *National Conference on Noise Control Engineering 1996 (NOISE-CON 96), Bellevue, Washington, USA*, 1996

7. **Sandberg U and Descornet G**, Road surface influence on tyre/road noise - Parts I and II.In *Inter-Noise 80. Miami, Florida, USA*, 1980

8. **Roe P G, Parry A R and Viner H E**, *High and low-speed skidding resistance: the influence of texture depth*, Transport Research Laboratory, 1998

9. **Phillips, S and Kinsey P**, Advances in identifying road surface characteristics associated with noise and skidding performance, In *SURF 2000 - Fourth PIARC International symposium on surface characteristics of roads and airfield. PIARC, Nantes*, 2000